LS-24
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APRIL 18,1985

ESTIMATION OF TOTAL RADIATIVE POWER FROM THE 6-GEV RING

Here we make an estimation of the total power radiated from a positron trajectory through the bending magnets, undulators and wigglers.

Bending Magnets

The power P_B per each bending magnet in the ring is given by

$$P_B \text{ (watts)} = 1.263 \times 10^3 \; B^2 \; (T^2) \;\; E^2 \; (GeV^2) \;\; I(Amp) \;\; L(m) \qquad (1)$$

where

E = 6 GeV

B = field average over the magnet length = 0.67 T

I = stored current = 0.1 A

L = trajectory in each dipole magnet = 2.95 m (Ref. LS-12)

This gives P_B = 6021 watts. Since there are 64 such dipoles in the ring, the total power radiated from dipoles is

$$P_B^T \text{ (watts)} = P_B \text{ (watts)} \times 64 = 385 \text{ kwatts}$$

Undulators

The total power radiated from a sinosoidal undulator is either given by

$$P_u \text{ (watts)} = 0.633 \times 10^3 \; E^2 \text{ (GeV}^2\text{)} \; I\text{(Amp)} \; B_o^2 \text{ (T}^2\text{)} \; L \text{ (m)} \qquad (2)$$

or by

$$P_u \text{ (watts)} = 7.25 \; E^2 \text{ (GeV}^2\text{)} \; I\text{(Amp)} \; N \; K^2/\lambda_o \text{ (cm)} \qquad (3)$$

where N = number of undulator periods of length λ_o (cm), K is the deflection parameter given by 0.934 B(T) λ_o (cm) and B_o is the peak magnetic field. For a conventional hybrid magnet B_o is given by

$$B_o(T) = 3.33 \exp[-G/\lambda_o \; (5.47 - 1.8 \; G/\lambda_o)] \qquad (4)$$

where G is the magnet gap in cm. In LS-22, we have discussed a spectrum of undulators suitable for the 6-GeV ring and discussed their parameters. The maximum power of 1555 watts was estimated for the undulator with λ_o = 4.8 cm and G = 2.29 cm. In this estimate, we will assume the power radiated by each of the undulators to be 2000 watts, although the actual power will be lower.

Wigglers

There will be definite need for wigglers on the 6-GeV ring, primarily to increase the critical energy of the emitted photon spectrum. The critical energy is given by

$$E_c \text{ (keV)} = 0.6651 \; B_o \text{ (T)} \; E_o^2 \text{ (GeV}^2\text{)} \qquad (4)$$

For the bending magnet it is 16.0 keV. For angiography application for example, we need to go above the iodine K-edge energy which is 33.169 keV. A wiggler with B_o = 1.4 T will have a spectrum with E_c = 33.5 keV. If we design a wiggler with a wavelength of 10 cm, the value of K is 13 which gives us a smooth photon energy spectrum. If there are 20 such poles (or 10 periods), the length of the trajectory through the field will be L = 1.0 m. Using Eq(2) or (3), we find the total radiated power from such a wiggler to be P_w = 4466 watts. For the estimation of total power we will accept 5000 watts to be the contribution from each of the wigglers.

Distribution of Insertion Devices and Estimate of Total Power

The Accelerator Physicists demand symmetry in the distribution of IDs in the ring for its optimal operation. From the user point of view, there is no unique way to distribute the IDs at the present time. It is however clear that the 6-GeV ring will have more undulators than wigglers. From the point of view of power estimation, it is better to include about the same number of wigglers and undulators since the wigglers radiate more power.

Assuming that the users will have 28 of the 32 straight sections available to them, for the estimation of power, we assign 16 of them for the undulators and 12 for the wigglers. The total radiated power is the

$$P_T \text{ (watts)} = 64 \times P_B + 16 \times P_u + 12 \times P_w$$

which gives 476 kWatts.

In Table 1, power radiated from the ring for various ID configurations are given.

Table 1. Power Radiated from 6-GeV ring with 100mA current

Bending Magnet @6kW	Undulators @2kW	Wigglers @5kW	Total Power (kW)
64	28	0	440
64	0	28	524
64	16	12	476

Need for Re-estimates

The above estimates are based on design which includes conventional type of IDs in the ring and a stored current of only 100mA. It is sure that both these may change as the design progresses. Certainly, some users will think of rather unusual IDs (either of longer length or of larger magnetic fields to generate larger flux of photons of higher energy) which will radiate more power. A continuing reevaluation of this estimate is recommended.